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# Implementation of Augmented Reality Technology in Virtual Practicum of High School Chemistry Subjects

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**ABSTRACT**

This research aims to investigate the implementation and effectiveness of Augmented Reality (AR) technology in virtual practicum activities for high school chemistry subjects. The study is motivated by the limited availability of laboratory facilities in many schools, which often hampers students' practical understanding of abstract and complex chemical concepts. By integrating AR into the learning process, students are provided with an interactive and immersive experience that simulates real laboratory experiments without the need for physical equipment. The research adopts a quasi-experimental method with a control and experimental group. The participants were 60 students from two different high schools, selected through purposive sampling. The experimental group engaged in virtual practicum using an AR-based application developed for this study, while the control group followed conventional practicum procedures. Data collection techniques included pre-tests and post-tests to measure students' conceptual understanding, as well as questionnaires and interviews to capture their engagement and perceptions. The results showed a significant increase in the post-test scores of the experimental group compared to the control group, indicating that AR-based virtual practicum had a positive impact on students' understanding of chemical reactions, molecular structures, and lab procedures. Additionally, students reported higher levels of motivation and interest, highlighting the immersive and visually rich environment provided by AR technology. In conclusion, the implementation of AR in virtual chemistry practicums presents a promising solution to address laboratory limitations while enhancing students' comprehension and engagement. This research recommends further development and integration of AR tools in science education to support interactive and cost-effective learning.



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## 1. INTRODUCTION

The development of educational technology in the 21st century has brought significant changes in the learning process, especially in science education. Chemistry, as one of the core science subjects in high school, emphasizes not only theoretical understanding but also practical skills through laboratory activities. However, in many schools, particularly in developing regions, limited access to laboratory equipment, chemicals, and safe environments often hinders the effectiveness of practicum-based learning. [1] This gap between theoretical

knowledge and practical application leads to a decline in students' conceptual understanding and learning motivation. [2]

To overcome these challenges, educators and researchers have begun exploring the integration of digital technologies into science learning. [3] One of the most promising innovations is the use of Augmented Reality (AR). AR blends digital content with the real world, allowing users to interact with virtual objects in a physical environment. In the context of chemistry education, AR can simulate laboratory experiments, visualize molecular structures, and demonstrate chemical reactions in a safe, interactive, and engaging manner. [4]

Previous studies have shown that AR has the potential to improve learning outcomes by enhancing students' spatial abilities, promoting active learning, and fostering curiosity. [5] Despite its potential, the application of AR in virtual practicum settings, particularly in high school chemistry subjects, remains underutilized and under-researched. [6] Most existing research focuses on AR in general learning contexts, with limited empirical evidence on its implementation and impact in simulating laboratory activities. [7]

This study aims to address that gap by implementing an AR-based virtual practicum in the high school chemistry curriculum and evaluating its effectiveness in improving students' conceptual understanding and engagement. The research specifically focuses on key chemistry topics that are traditionally difficult to comprehend through theory alone, such as molecular geometry, acid-base reactions, and redox processes. [8]
The objectives of this research are: [9]
a. To design and implement a virtual practicum application using AR technology tailored for high school chemistry topics. [10]
b. To compare the effectiveness of AR-based virtual practicum with conventional practicum in improving students' learning outcomes. [11]
c. To analyze students' responses and perceptions regarding the use of AR in their chemistry learning experience. By integrating AR technology into virtual practicum activities, this study aims to provide an alternative and innovative approach to science education that is both effective and accessible. The findings are expected to contribute to the development of future-oriented educational practices that leverage technology to enhance both teaching and learning processes. [12]

## 2. METHOD

### 2.1 Research Design

This study employed a quasi-experimental research design with a non-equivalent control group pre-test and post-test structure. This design was selected to measure the effectiveness of augmented reality (AR) in virtual practicum settings by comparing the learning outcomes between a group of students using AR technology and a group undergoing conventional laboratory practices. [13]

### 2.2 Participants

The participants of this study consisted of 60 eleventh-grade high school students from two public schools in Mumbai, selected through purposive sampling. The sample was divided into two groups: [14]
a. Experimental group (n = 30): Students who participated in the AR-based virtual practicum.
b. Control group (n = 30): Students who conducted conventional hands-on chemistry experiments. All participants had previously studied the same chemistry topics in class to ensure equal prior knowledge.

### 2.3 Research Instruments

Several instruments were used to collect quantitative and qualitative data: [15]
a. Pre-test and Post-test: A set of 20 multiple-choice and short-answer questions was developed to assess students' conceptual understanding of the selected chemistry topics, including molecular structures, acid-base reactions, and redox processes.
b. Student Questionnaire: A 5-point Likert scale questionnaire was used to evaluate students' engagement, motivation, and perception toward the use of AR in the practicum.
c. Observation Sheet: Used to record student behavior, interaction, and participation during practicum sessions.
d. Semi-structured Interviews: Conducted with selected students and teachers to gather in-depth insights about their experiences and opinions.

### 2.4 Development of AR-Based Practicum Application

An AR application specifically designed for this research was developed using Unity 3D and Vuforia SDK. The application enabled students to visualize and interact with 3D molecular models, perform virtual experiments, and observe simulated chemical reactions. The content was aligned with the national high school chemistry curriculum and reviewed by subject-matter experts for validity.

### 2.5 Procedure

The research was conducted over a period of four weeks. The procedure was as follows:
Week 1: Administration of pre-tests to both groups to measure prior knowledge.

Week 2–3: The experimental group used the AR-based application to complete virtual practicum sessions in a classroom with tablets or smartphones. The control group performed the same experiments using traditional laboratory tools and materials.
Week 4: Post-tests were administered to both groups. Subsequently, questionnaires and interviews were conducted with students and teachers.

2.6 Data Analysis

Quantitative data from the pre-tests and post-tests were analyzed using descriptive statistics (mean, standard deviation) and inferential statistics (paired sample t-test and independent sample t-test) to determine the significance of the differences between groups. Qualitative data from questionnaires and interviews were analyzed using thematic analysis to identify common themes and student perceptions regarding the use of AR technology.

2.7 Validity and Reliability

The research instruments were validated by two chemistry education experts and tested in a pilot study involving 10 students. The reliability of the questionnaire was confirmed with a Cronbach's Alpha value of 0.87, indicating high internal consistency.

## 3. RESULTS AND DISCUSSION

3.1 Results

The findings of this study are presented in two main categories: (1) students' learning outcomes based on pre-test and post-test scores, and (2) student perceptions based on questionnaires and interviews.

3.1.1 Learning Outcomes

The results of the pre-test showed that the mean scores of the experimental group ($M = 58.3$, $SD = 9.1$) and the control group ($M = 57.9$, $SD = 8.8$) were statistically similar, indicating comparable initial knowledge between both groups. After the intervention, the post-test results demonstrated a significant difference. The experimental group achieved a higher mean score ($M = 83.7$, $SD = 6.4$) compared to the control group ($M = 74.2$, $SD = 7.1$). A paired sample t-test showed a significant improvement in the experimental group's scores ($t = 12.45$, $p < 0.001$), while the control group also experienced improvement, though to a lesser extent ($t = 7.38$, $p < 0.001$). An independent sample t-test comparing post-test scores between the two groups revealed a statistically significant difference ($t = 5.21$, $p < 0.001$), suggesting that the use of AR in virtual practicum significantly enhanced students' understanding of the chemistry concepts.

3.1.2 Student Perceptions and Engagement

Data from the student questionnaire indicated a positive response to the AR-based practicum experience. Over 90% of students in the experimental group agreed or strongly agreed that the AR application made learning more engaging, improved their visualization of molecular structures, and helped them understand abstract concepts more easily. Key responses from the interviews supported the quantitative findings. Students expressed excitement about using AR, stating that it felt like a game but with educational value. Several students mentioned that the ability to "see and interact" with 3D molecules and reactions made the subject more memorable and less intimidating. Teachers also noted increased participation and curiosity among students during AR sessions.

3.2 Discussion

The results of this study confirm the hypothesis that integrating Augmented Reality into virtual chemistry practicum positively impacts student learning outcomes and engagement. The significant improvement in post-test scores among the experimental group indicates that AR helps bridge the gap between theoretical knowledge and practical understanding—especially in topics that are abstract or difficult to visualize, such as molecular geometry and chemical reactions. The immersive nature of AR provides a multisensory learning experience, which aligns with constructivist learning theories that emphasize active student engagement and the use of concrete representations in learning. This supports the findings of earlier studies, such as those by Ibáñez and Delgado-Kloos (2018), which highlight AR's effectiveness in science education due to its interactive, visual, and exploratory nature.

Furthermore, the positive student perceptions suggest that AR technology not only facilitates comprehension but also increases motivation. Students are more likely to retain knowledge when they are actively involved and emotionally engaged. The novelty and interactivity of AR appear to stimulate interest, reduce cognitive load, and improve focus, which are essential factors in effective learning.

Despite these advantages, the implementation of AR in classrooms requires sufficient infrastructure, teacher training, and time for integration into the curriculum. While the technology is promising, it should complement—not replace—traditional methods, particularly for experiments that require tactile experiences or chemical safety practices.

Table 1. Pre-test and Post-test Scores of Experimental and Control Groups

| Group | N | Pre-test Mean (SD) | Post-test Mean (SD) | Mean Ga |
|---|---|---|---|---|
| Experimental | 30 | 58.3 (±9.1) | 83.7 (±6.4) | 25.4 |
| Control | 30 | 57.9 (±8.8) | 74.2 (±7.1) | 16.3 |
| Experimental | 30 | 58.3 (±9.1) | 83.7 (±6.4) | 25.4 |

Table 2. Paired t-Test Results (Pre-test vs. Post-test)

| Group | t-value | p-value | Significance |
|---|---|---|---|
| Experimental | 12.45 | < 0.001 | Significant |
| Control | 7.38 | < 0.001 | Significant |
| Group | t-value | p-value | Significance |

Table 3. Independent t-Test on Post-test Scores

| Group Comparison | t-value | p-value | Significance |
|---|---|---|---|
| Experimental vs. Control | 5.21 | < 0.001 | Significant |

## 4. CONCLUSION

This study investigated the implementation of Augmented Reality (AR) technology in virtual practicum sessions for high school chemistry subjects and its impact on students' conceptual understanding and engagement. The findings provide compelling evidence that AR-based virtual practicums can significantly enhance learning outcomes compared to conventional laboratory methods. Students in the experimental group showed a greater increase in post-test scores, indicating that the immersive and interactive nature of AR helped bridge the gap between abstract theoretical knowledge and practical understanding.

Moreover, student perceptions collected through questionnaires and interviews revealed a highly positive attitude toward the use of AR. Students found the AR-based learning environment more engaging, enjoyable, and helpful in visualizing complex chemistry concepts such as molecular geometry and chemical reactions. These positive responses also translated into increased motivation and participation during practicum sessions.

The results suggest that AR can serve as a valuable supplementary tool in science education, especially in schools where access to physical laboratory equipment is limited. Its ability to simulate real-life experiments in a safe, cost-effective, and interactive way opens new opportunities for improving the quality of STEM education.

However, successful implementation of AR in educational settings requires adequate infrastructure, teacher training, and thoughtful integration into the curriculum. It is also important to ensure that the use of AR complements rather than replaces hands-on laboratory experiences when possible.

In conclusion, the integration of AR in virtual chemistry practicums presents a promising innovation in educational technology that can enhance student learning, foster deeper conceptual understanding, and increase motivation. Future research is recommended to explore the long-term effects of AR on student achievement and its applicability across other science domains and education levels.

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